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⑯ Methods of producing hybrid DNA sequences and hybrid polypeptides and DNA sequences produced by them.

⑯ A method for preparing hybrid DNA sequences characterized by the steps of (a) preparing a DNA fragment, or concatemer thereof, said fragment comprising in sequence one of the parental DNA sequences from which the hybrid DNA sequence is to be derived, an intact replicon such that the DNA fragment may be replicated in a host cell, and the other parental DNA sequence from which the hybrid DNA sequence is to be derived, the two parental DNA sequences having a sequence of at least three, and preferably at least five, nucleotides in common in the location where hybrid DNA sequence formation is sought and the direction of translation of the coding sequences in the two parental sequences being the same relative to each other in the DNA fragment; (b) selecting host cells that have been transfected with the desired hybrid DNA sequence and isolating said hybrid DNA sequence from them. The hybrid DNA sequences of this invention are useful in producing hybrid polypeptides having a variety of uses and biological activities.

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METHODS OF PRODUCING HYBRID DNA SEQUENCES
AND HYBRID POLYPEPTIDES AND
DNA SEQUENCES PRODUCED BY THEM

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TECHNICAL FIELD OF INVENTION

This invention relates to hybrid polypeptides, the DNA sequences coding for them and to methods of producing those DNA sequences and polypeptides. The methods of this invention are characterized by the steps of

10 10 (a) preparing a DNA fragment or concatemer thereof, said fragment comprising in sequence one of the parental DNA sequences from which the hybrid DNA sequence is to be derived, an intact replicon such that the DNA fragment may be replicated in a host cell, and the other parental

15 15 DNA sequence from which the hybrid DNA sequence is to be derived, the two parental DNA sequences having a sequence of at least three, and preferably at least five, nucleotides in common in the location where hybrid DNA formation is sought and the direction of translation of the coding

20 20 sequences in the two parental sequences being the same relative to each other in the DNA fragment; and (b) selecting host cells that have been transfected with the desired hybrid DNA sequence and isolating said hybrid DNA sequence from them. Selection of the desired host cells

25 25 may be facilitated by having each parental DNA sequence associated with a different antibiotic resistance marker and growing the transformed host cells on agar plates, containing both antibiotics. The hybrid DNA sequences

produced by the methods of this invention enable the production of novel hybrid polypeptides having a variety of uses and biological activities.

BACKGROUND ART

5 Recent advances in recombinant DNA technology and molecular biology have enabled the isolation and identification of a variety of DNA sequences and genes that code for a large number of different polypeptides. For example, DNA sequences coding for the ten or more human
10 α -interferons are described in C. Weissmann et al., Phil. Trans. R. Soc. Lond. B299, pp. 7-28 (1982). DNA sequences coding for human β -interferon and human γ -interferon are described in R. Derynck et al., Nature 285, pp. 542-547 (1980) and R. Devos et al., Nucleic Acids Research 10, pp. 2487-2501 (1982), respectively.

15 DNA sequences coding for non-interferon polypeptides are also available. They include DNA sequences coding for human insulin [D. Goeddel et al., Proc. Natl. Acad. Sci. USA 76, pp. 106-110 (1979)], rat insulin [L. Villa-Komaroff et al., Proc. Natl. Acad. Sci. USA 75, pp. 3727-3731 (1978)], human growth hormone [D. Goeddel et al., Nature 281, pp. 544-548 (1979)] and bovine growth hormone [W. Miller et al., DNA 1, pp. 37-50 (1981); W. Miller et al., Endocrinology 107, pp. 851-854 (1980)].
20 DNA sequences coding for a variety of viral antigens are also available. These include DNA sequences encoding the viral antigens of hepatitis B virus [M. Pasek et al., Nature 282, pp. 575-579 (1979); C. Burrell et al., Nature 279, pp. 43-47 (1979)] and the DNA sequences encoding the viral antigens of foot and mouth disease virus [H. Küpper et al., Nature 289, pp. 555-559 (1981)].

25 Certain hybrid DNA sequences consisting of parts of two or more of the above-described DNA sequences are also available. These hybrids are conventionally prepared
30 by using restriction sites that occur in the various DNA sequences and ligating two restricted fragments together

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at a common restriction site or by blunt-end ligation of different restriction fragments to produce the hybrid DNA sequence. These hybrid DNA sequences may then be employed to transform appropriate host cells and to produce the 5 hybrid polypeptide coded for by them. For example, hybrid DNA sequences of human $\alpha 1$ and $\alpha 2$ interferon, and the hybrid interferons coded for by them, have been prepared using this restriction and ligation method [M. Streuli et al., Proc. Natl. Acad. Sci. USA 78, pp. 2848-2852 (1981), 10 R. Lawn et al., Nucleic Acids Res. 9, pp. 1045-1052 (1981)].

Depending on the particular construction and components of these hybrid interferons, they may display similar or vastly different specificities, activities and 15 properties than the parental polypeptides from which they are derived. For example, although the specific activity of human $\alpha 1$ interferon is comparatively low in human cells and comparatively high in mouse cells, hybrids of $\alpha 1$ and $\alpha 2$ carrying the N-terminal half of $\alpha 2$ have high activity 20 in human cells.

Although these prior methods have permitted the formation of certain hybrid DNA sequences and their use in the synthesis of certain hybrid polypeptides, they are very limited in their application. For example, hybrid 25 formation by these prior methods requires the existence of a restriction site in both DNA sequences at the point where hybrid formation is desired. More usually, these methods require digestion of the DNA sequences from a convenient restriction site to the point where hybrid formation is desired and determination of when the digestions have reached the correct nucleotide. This is a 30 very laborious and time consuming undertaking. Moreover, in DNA sequences that are closely related like the α -interferons, in order to avoid deleting or adding nucleotides in one or both of the DNA sequences, the restriction 35 sites or digestions have to be in homologous portions of the DNA sequences. Such convenient restriction sites,

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digestions and homologies are plainly often not available. Furthermore, even in the few instances when such restriction sites are available, the number of possible hybrids able to be made from them is very small and their preparation very time consuming.

5 Therefore, there is a need in the recombinant DNA art to develop new methods for forming hybrid DNA sequences that do not depend on the chance availability of appropriate restriction sites in the two DNA sequences

10 10 which one seeks to combine or in sequential deletions from one or both of those sites in order to produce products of modified use, activity and specificity, as compared to the polypeptides coded for by their parental DNA sequences.

DISCLOSURE OF THE INVENTION

15 15 This invention solves the above-described problems and avoids the disadvantages that beset prior methods of hybrid DNA sequence formation. It provides for the first time novel hybrid polypeptides, the DNA sequences that code for them and methods of producing those DNA sequences and polypeptides.

20 20 The novel hybrid DNA sequences of this invention are characterized by at least two connected sequences of nucleotides, the first sequence of nucleotides being connected to the second sequence of nucleotides in their original reading frames and so as to maintain constant that reading frame in each sequence through a DNA sequence of at least three, and preferably at least five, nucleotides that was common to or inserted into both parental DNA sequences at the location where hybrid formation was sought. These novel DNA sequences encode the hybrid polypeptides of this invention and enable their production in appropriately transformed hosts.

25 30 The methods of this invention enable the construction of those hybrid DNA sequences and polypeptides in a simple and efficient manner.

In one embodiment of the method of this invention, where the two parental DNA sequences from which the hybrid DNA sequence is to be derived originally have a sequence of at least three, and preferably at least five, 5 nucleotides, and more preferably at least 8, and most preferably at least 13 nucleotides, in common, in the location where hybrid DNA sequence formation is sought, the method comprises the steps of (a) preparing a DNA fragment or more usually a concatemer thereof, said fragment comprising in sequence one of the parental DNA 10 sequences from which the hybrid DNA sequence is to be derived, an intact replicon such that the DNA fragment may be replicated in a host cell, and the other parental DNA sequence from which the hybrid DNA sequence is to be 15 derived, the two parental DNA sequences having a sequence of at least 3, and preferably at least 5, nucleotides in common in the location where hybrid DNA formation is sought and the direction of translation of the coding sequences in the two parental sequences in said fragment 20 being the same relative to each other; and (b) selecting host cells that have been transfected with the desired hybrid DNA sequence and isolating said hybrid DNA sequence from them.

In another embodiment of the method of this invention, where the two parental DNA sequences from which the hybrid DNA sequence is to be derived do not originally have a sequence of at least three, and preferably at least five, nucleotides in common at the location where hybrid DNA sequence formation is sought, the method comprises the 25 steps of (a) preparing a linear DNA fragment or a concatemer thereof, said fragment comprising in sequence one of the parental DNA segments from which the hybrid DNA sequence is to be derived, an intact replicon such that the fragment may be replicated in a host cell, the other 30 of the parental DNA sequences from which the hybrid DNA sequence is to be derived, the direction of translation of the coding sequences in the two parental sequences being 35

the same relative to each other in the DNA fragment; (b) forming in one of said parental DNA sequences at the location where said hybrid formation is sought a sequence of at least three, and preferably at least five, nucleotides, 5 said nucleotide sequence being identical to and in the same reading frame as a DNA sequence at the location where said hybrid formation is sought in said other parental DNA sequence; and (c) selecting host cells that have been 10 transfected with the desired hybrid DNA sequence and isolating said hybrid DNA sequences from them.

It should of course be understood that in this embodiment of our invention the formation of the common nucleotide sequence in one or the other DNA sequence may be done prior to preparing the DNA fragment. Moreover, 15 it should be also understood that the necessary homology in the two parental DNA sequences could also be provided by inserting into both DNA sequences the same or similar sequences so as to build the required sequence homology into both sequences before or after preparing the DNA fragment. 20

In the more preferred embodiment of this invention, each of the parental DNA sequences is also associated with a different antibiotic resistance marker. In this preferred embodiment, selection of the desired host cells 25 may be facilitated by growing the transformed host cells on agar plates containing both antibiotics. This preferred method of selection is very useful in this invention from a practical standpoint because the yield of desired recombinants or hybrid DNA sequences is low and even a minute 30 contamination with one or the other parental DNA sequences or with DNA sequences resulting from the ligation of two identical parental DNA sequences may result in a high level of unwanted transformants that would be difficult to screen in order to select the desired hybrid without such dual 35 antibiotic resistance.

In still another embodiment of this invention, the circularization and ligation step to form the hybrid

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DNA sequence is done in vitro, leaving only heteroduplex repair to take place in the host cell after its transfection with that hybrid DNA sequence. In this less preferred embodiment, the ends of the DNA fragment, or concatemer

5 thereof, are rendered single-stranded before in vitro circularization and ligation.

The DNA sequences of this invention are characterized by at least two connected sequences of nucleotides, each connected DNA sequence being derived from a different

10 parental DNA sequence, the first sequence of nucleotides being connected to the second sequence of nucleotides in the original reading frame and so as to maintain constant that reading frame in each sequence through a DNA sequence of at least three, and preferably at least five, nucleo-

15 tides that was common to or inserted into both parental DNA sequences at the location where hybrid formation was sought. These DNA sequences enable the production of novel proteins and polypeptides having a variety of uses and biological activities.

20

BRIEF DESCRIPTION OF FIGURES

Figure 1 is a schematic outline of one embodiment of a method of preparing the hybrid DNA sequences of this invention.

25 Figure 2 is a schematic outline of another embodiment of an in vitro method of preparing the hybrid DNA sequences of this invention.

Figure 3 is a schematic outline of a third embodiment of a method of preparing the hybrid DNA sequences of this invention.

30 Figure 4 is a schematic outline of the embodiment of this invention depicted in Example I.

Figure 5 is a schematic outline of the construction of pM11Kan-Xba.

35 Figure 6 displays the nucleotide sequences of IFN- α 1 and IFN- α 2 and 11 crossover regions A-K where

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hybrids were isolated using one embodiment of the methods of this invention.

Figure 7 is a graphical display of the antiviral activities of various $\alpha_2-\alpha_1$ hybrid interferons on different target cells.

Figure 8 is a schematic outline of one embodiment of a method of this invention for constructing $\alpha_2-\beta$ hybrid interferons.

Figure 9 displays the nucleotide sequences of IFN- β and IFN- α_2 aligned by computer for "maximum sequence homology" and four crossover regions F3, F8, F10 and F15 where hybrids were isolated using one embodiment of the methods of this invention.

Figure 10 is a schematic outline of one embodiment of a method of this invention for constructing human α_2 -mouse α_2 hybrid interferons.

BEST MODE OF CARRYING OUT THE INVENTION

In order that the invention herein described may be more fully understood, the following detailed description is set forth.

Referring now to Figure 1, we have depicted one preferred embodiment of a method according to this invention for preparing the novel hybrid DNA sequences of this invention. The two parental DNA sequences depicted in Figure 1, sequences 1 and 2, from which the hybrid DNA sequence is derived, have a sequence (3) of at least three, and preferably at least five, and more preferably at least 8, and most preferably at least 13 nucleotides, in common in the location where hybrid DNA sequence formation is sought.

As depicted in Figure 1, parental sequences 1 and 2 are part of plasmids or other cloning vehicles. However, it is to be understood that the parental DNA sequences useful in the methods of this invention may be derived from any source of DNA sequences provided that upon combination they form a DNA fragment (fragment 5 in

Figure 1), or a concatamer thereof, said fragment comprising in sequence one of the parental DNA sequences, an intact replicon (4 in Figure 1) such that the fragment may be replicated in a host cell, and the other parental

5 DNA sequence, the two parental DNA sequences having a sequence of at least three, and preferably at least five, nucleotides in common in the location where hybrid DNA formation is sought and the direction of translation of coding sequences in the two parental sequences being the
10 same relative to each other in the DNA fragment. Such sources of DNA sequences include, for example, natural sources, synthetic sources, semisynthetic sources, cDNA libraries and combinations of them.

In the embodiment depicted in Figure 1, DNA
15 fragment 5 comprises parental DNA sequences 1 and 2 and intact replicon 4. It also comprises antibiotic resistance markers A associated with the first parental DNA sequence and antibiotic resistance markers B associated with the second parental DNA sequences.

20 DNA fragment 5 in that embodiment was prepared by first linearizing the plasmids carrying parental DNA sequences 1 and 2 using a restriction site located outside of the respective parental DNA sequences. The restriction site used for such linearization need not be the same in
25 both plasmids, although preferably the same site is employed for ease of combination of the two resulting fragments through the compatible restriction residues. However, it is to be understood that various means of combining the two fragments that do not require the same
30 restriction residues may also be employed in the methods of this invention. These means, for example, include tailing, blunting, fill-in and synthetic linkers, as well as use of two different restriction sites which yield the same overhanging ends, for example, BglII and BamHI.

35 In the embodiment depicted in Figure 1, the linearized plasmids were next restricted (Restriction Sites B) to remove that portion of the linearized plasmid

located before the start of parental DNA sequence 1 and that portion of the linearized plasmid located after the end of parental DNA sequence 2. The resulting DNA fragments were then combined to form Fragment 5, or a concatemer thereof, said fragment having only one replicon and the direction of translation of the two coding sequences from the parental DNA sequences being the same relative to each other in the DNA fragment. Fragment 5 also carries antibiotic resistance markers A and B, respectively associated with the two different parental DNA sequences to facilitate selection of the desired fragment construction.

Again, it is to be understood that the particular sequence of steps employed in the embodiment of this invention depicted in Figure 1 is not required to construct DNA sequence 5 employed in this invention to prepare the novel hybrid DNA sequences of this invention. For example, although it is preferred that the DNA sequence 5 start at one end with the first parental DNA sequence and end at the other end with the other parental sequence, DNA sequences that begin and/or end outside of the parental DNA sequences may also be used in the methods of this invention, provided the additional nucleotide sequences do not occur elsewhere in the sequence chosen. DNA sequences that begin and/or end within the parental DNA sequences are also useful in this invention. All that is required for the method of this invention is that the DNA sequence 5 comprise in sequence one parental DNA sequence (1), an intact replicon (4) and the other parental DNA sequence (2), the two parental DNA sequences having a sequence of at least three, and preferably at least five, nucleotides in common in the location where hybrid DNA formation is sought and the direction of translation of the coding sequences in the two parental DNA sequences being the same relative to each other in the fragment.

In the embodiment depicted in Figure 1, circularization of DNA sequence 5 and overlap of the homologous

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sequences of nucleotides in the location where hybrid formation is sought in both parental DNA sequences is effected in vivo by the host cell which is transfected by the DNA sequence. The host cell used for this transfection
5 should be recombination proficient, and preferably be rec A+. In the embodiment depicted in Figure 1, the host cell effects combination of the parental DNA sequences within that region of DNA sequence homology and heteroduplex repair to form a vector or plasmid that contains the
10 desired hybrid DNA.

It should, however, also be understood that recircularization and recombination of the DNA sequences may also be done in vitro using conventional means and the host employed only to effect heteroduplex repair. See, 15 for example, Figure 2. However, because it involves more biochemical steps, in vitro combination is less preferred in the practice of this invention.

In the preferred embodiment of this invention, depicted in Figure 1, the parental DNA sequences had the 20 required homology pre-existing at the location where hybrid DNA sequence formation was desired. Such parental DNA sequences include, for example, the fifteen or more human leukocyte interferons, the various animal leukocyte interferons, including mouse, bovine, porcine, equine and 25 chicken, human fibroblast interferon, which is characterized by stretches of homology of up to 13 nucleotides as compared to the leukocyte interferons, animal fibroblast interferons, human immune interferon and animal immune interferons. They may also include various related 30 lymphokines and the antigens to the various strains and serotypes of foot and mouth disease virus.

In a less preferred embodiment of this invention, the parental DNA sequences do not have the required 35 homology. Accordingly, in that embodiment, which is depicted in Figure 3, the required homology is added to one or both of the parental DNA sequences in vitro by adding a sequence of nucleotides that corresponds to the

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sequence of nucleotides in the other parental DNA sequence or some predetermined sequence at the location where hybrid DNA sequence formation is sought. After providing the required homology to the two parental DNA sequences, 5 the steps in the method of this invention, previously described, may be usefully employed in this embodiment to produce the novel hybrid DNA sequences of this invention. Therefore, the method of this invention is applicable to any parental DNA sequence.

10 Having prepared the novel hybrid DNA sequences of this invention by the methods described above, those sequences may then be employed to produce the novel polypeptides coded for by them. Various known methods and hosts may be employed to express these hybrid DNA 15 sequences to produce those novel polypeptides. For example, the hybrid DNA sequence may be isolated from the plasmid produced in the above-described method, inserted into various known expression vectors under the control of various known expression control sequences and employed to 20 transform various hosts, which upon culturing will produce the desired polypeptides.

Expression control sequences are sequences of nucleotides that control and regulate the expression of DNA sequences when operatively linked to those sequences 25 in expression vectors. Those useful in expressing the novel hybrid DNA sequences of this invention include, but are not limited to, the lac system, trp system, the major operator and promoter regions of phage λ , the control regions of fd coat protein, the β -lac system, the TAC system, the TRC System, and other sequences known to control the expression of genes of prokaryotic or eukaryotic 30 cells or their viruses or combinations thereof.

Hosts useful in accordance with this invention for preparing the hybrid DNA sequences of this invention 35 in vivo and for expressing those hybrid DNA sequences include various strains of E.coli, e.g., E.coli HB101, E.coli 1776, E.coli 2282, E.coli MRCI, E.coli SK1592 and

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E.coli 803, Pseudomonas, Bacillus, including Bacillus subtilis and Bacillus stearothermophilus, yeasts and other fungi, animal, including Chinese Hamster ovary cells, or plant hosts and human cells in culture. For transfection

5 to produce the hybrid DNA sequence, the strains should be recombination proficient and more preferably be rec A+. Of course not all host/expression vector combinations may be equally efficient for the formation of or expression of a particular hybrid DNA sequence. However, the particular 10 selection of a host/vector combination may be made by those of skill in the art without departing from the scope of this invention.

Similarly, methods of inserting the hybrid DNA sequence into the above-described expression vectors, 15 transforming the above-described host or culturing those hosts may be chosen from among various well-known methods without departing from the scope of this invention.

The novel polypeptides produced using the hybrid DNA sequences of this invention have a variety of uses.

20 For example, the hybrid α -interferons produced by this invention have various activities in certain cells and various specific activities. Accordingly, such hybrids are useful in modifying the anti-viral and anti-cancer activities of the parental interferons for use in specific 25 cells or against specific diseases. In like manner, hybrid proteins from the antigens of foot and mouth disease are useful in di- or multivalent vaccines against various strains and serotypes of foot and mouth disease virus.

30 In order to describe this invention so that it may be more clearly understood, the following examples are set forth. These examples are for the purpose of illustration and any specific enumeration therein should not be construed as a limitation of this invention.

35 The enzymes that we used in these examples were purchased from New England Biolabs Inc. We purchased the labeled nucleotides from Amersham. And, we acquired the

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E. coli strains as follows: SK1592 from Dr. S. Kushner, University of Georgia; 803 from Dr. K. Murray, University of Edinburgh; and CaCl_2 -treated SK1592 was a gift from M. Streuli.

5 We prepared the plasmids containing the parental $\alpha 1$ and $\alpha 2$ interferon genes by modifications of published methods [T. Currier et al., Anal. Bioch. 76, pp. 431-441 (1976); D. Holmes et al., Anal. Bioch. 114, pp. 193-197 (1981)].

10

EXAMPLE 1

Example 1 demonstrates the formation of hybrid DNA sequences coding for human $\alpha 1/\alpha 2$ hybrid interferons in vivo using the recombination machinery of E. coli and the production of such hybrid proteins in E. coli. The 15 DNA sequences for $\alpha 1$ and $\alpha 2$ human interferon are described, for example, in M. Streuli et al., "At Least Three Human Type α Interferons: Structure of $\alpha 2$ ", Science, 209, pp. 1343-47 (1980). See also European patent application 32134 and clones deposited and made available in connection therewith.

20

We constructed plasmid pM21 (constructed for high expression of interferon $\alpha 2$ in E. coli) by fusing the DNA sequence coding for mature $\alpha 2$ interferon to the initiation codon of the β -lactamase gene of plasmid pBR322. In 25 that construction the interferon coding sequence and its 3'-non-coding sequence replaced the β -lactamase coding sequence down to the PstI site, where it was linked to the β -lactamase sequence by a poly(dGC) sequence. The remainder of the plasmid was identical to pBR322, including 30 its intact tetracycline resistance coding region (Figure 4). See also European patent application 32134; ATCC 31769.

35

We constructed the other parental plasmid, pM11kan, by inserting the $\alpha 1$ interferon coding sequence into a derivative of pBR322, in substantially the same way that we inserted the coding sequence for $\alpha 2$ interferon

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into pBR322 to obtain the pM21 plasmid (Figure 4). More specifically, we first prepared a derivative of pBR322 that included the genes coding for resistance to tetracycline, ampicillin and kanamycin (pBR322kan), as

5 described below. First, we partially digested pBR322 with HaeII in the presence of 50 μ g/ml ethidium bromide to yield mostly full-size linear molecules. We then ligated these fragments to an equivalent amount of a 1430 bp fragment prepared by complete HaeII digestion of a derivative
10 of pCRI (a gift of M. Billeter). This fragment contained the gene coding for kanamycin resistance. We then selected transformants for resistance to kanamycin and ampicillin, and subsequently for resistance to tetracycline. For some reason, the simultaneous selection for resistance to all
15 three antibiotics did not result in any surviving transformants.

Restriction mapping of our selected transformants demonstrated that in our construction the kanamycin resistance gene, contained in the 1430 bp HaeII fragment
20 of pCRI, had been inserted into the HaeII site of pBR322 at position 2352 (Figure 4).

We then prepared pMllkan by combining the following DNA sequences: (1) the 4400 bp PstI-SalI fragment of the above-described kanamycin resistant pBR322 derivative (pBR322kan), (2) the 1000 bp Clal-PstI fragment of pMll, containing the interferon α 1 coding sequence, and
25 (3) the about 800 bp Clal-SalI fragment of a pBR322 derivative (pBR322Bam^R), containing a lambda DNA fragment linked by poly (dG:dc) tracts inserted in the BamHI site
30 where it inactivated the gene coding for tetracycline resistance present in that fragment. We had isolated the three fragments, described above, by electrophoresis on low-melting agarose gels (Sea Plaque agarose, FMC Corporation) and used the gel slices after melting them at 65°C
35 directly for ligation. We selected transfectant colonies for kanamycin resistance and then on the basis of their tetracycline and ampicillin sensitivity. We confirmed the

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structure of the desired pMllkan by restriction mapping (Figure 4).

To prepare the hybrid DNA sequences of this invention, we linearized pMllkan and pM21, and combined 5 fragments thereof to prepare a DNA fragment, or more usually a concatemer thereof, said fragment containing both parental DNA sequences and an intact replicon. The fragment also contains one antibiotic resistance marker (Kanamycin) and a portion of another antibiotic resistance 10 marker (tetracycline) associated with the $\alpha 1$ coding sequence and the portion of the tetracycline resistance marker that completes it associated with the $\alpha 2$ coding region. As a result, selection of the desired hybrid DNA is facilitated because only correctly constructed fragments 15 will display both antibiotic resistances.

To prepare this DNA fragment, we restricted pM21 with SalI and PstI and isolated the 1580 bp SalI-PstI fragment of pM21 (Figure 4). We also restricted pMllkan with SalI and BglII and isolated the 4970 bp SalI-BglII 20 fragment of pMllkan. We isolated these fragments from the digests by electrophoresis on low melting agarose (1.2% and 0.8%, respectively) in 40 mM Tris-acetate, 1 mM EDTA (pH 7.8). We then ligated the two fragments together at 16°C for 18 h in a 20 μ l reaction mixture, containing 20 25 mM Tris-HCl (pH 7.8), 10 mM MgCl₂, 10 mM DTT, 0.5 mM ATP, 10-20 fmol DNA fragments from melted slices of the agarose (2-5 μ l aliquots of agarose slices method at 65°C, final agarose concentration 0.35%) and DNA ligase (400 units, obtained from New England Biolabs).

30 The resulting DNA fragment (Figure 4) comprised in sequence the DNA sequence encoding mature $\alpha 2$ interferon, the DNA sequences encoding tetracycline resistance and kanamycin resistance, an intact replicon from pBR322 and the DNA sequence encoding the COOH-terminal part of $\alpha 1$ 35 interferon. Moreover, the parental $\alpha 1$ and $\alpha 2$ DNA sequences were in the correct translational orientation relative to each other in the DNA fragment to allow

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parallel overlap of homologous sequences of at least 3 nucleotides at the location where hybrid formation was sought. Accordingly, circularization of this DNA sequence by the methods of this invention produced hybrid DNA

5 sequences encoding the amino terminal of $\alpha 2$ and the carboxy terminal of $\alpha 1$, with the location of hybrid formation being downstream of the BglII site in the $\alpha 1$ coding region.

In order to circularize the DNA fragment and to form the desired hybrid DNA sequences, we transfected the 10 DNA fragment into calcium chloride-treated E.coli SK1592 [prepared according to Cohen et al., Proc. Natl. Acad. Sci. USA, 68, pp. 2110-2114 (1972), and stored at -80°C in a solution of 50 mM CaCl₂ in 20% glycerol]. We employed 100 μ l transfection mixtures, containing 2.5 μ l aliquots 15 of the ligated DNA, 10 mM CaCl₂, 10 mM MgCl₂, 10 mM Tris-HCl (pH 7.5) and 65 μ l of a suspension of the CaCl₂-treated E.coli cells. We then maintained the resulting suspensions at 0°C for 15 min and then at 42°C for 2 min, diluted them with 1 ml of L-broth and incubated them for 90 min at 20 37°C with shaking.

We then spread aliquots of the mixture of transformed cells on agar plates, containing L-broth, kanamycin (50 μ g/ml) and tetracycline (20 μ g/ml). This selection process ensured that only cells transformed with DNA 25 sequences containing elements of both parental DNA fragments linked correctly at the SalI site gave rise to viable colonies because in our selection the proximal portion of the tetracycline resistance region has to be provided by the $\alpha 2$ -containing fragment whereas the distal 30 portion of the tetracycline resistance region as well as the kanamycin resistance gene must originate from the $\alpha 1$ -containing fragment (Figure 4).

In two separate experiments, we obtained 3 and 47 positive colonies, respectively, from transfection of 35 portions (containing 1-2 fmol fragments) of the above ligation mixtures. The small number of colonies that we obtained in the first experiment may be due to the fact

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that the agarose-containing ligation mixture we used in that experiment had been melted at 65°C once before and stored subsequently at -25°C for several days prior to its use. In subsequent experiments the number of colonies varied between 1600 and 90000 per pmol DNA fragments.

5 We isolated plasmids from the cultures selected above by well-known methods and analyzed the plasmids by restriction and DNA sequence analysis [L. Guo et al.,
10 Nucl. Acids Res., 10, pp. 2065-2084 (1982)]. We have summarized the results of our analyses in Table I.

15 With the exception of clone 12.1, which contained a deletion, the clones analyzed represented correctly recombined hybrid DNA sequences without any gaps or insertions. Our conclusion is supported by (1) the distances between the BglII sites and the flanking restriction sites on the 5' and 3' sides of the interferon insert (Figure 4), (2) sequence determinations of relevant portions of 21 plasmids, and (3) the fact that the bacterial cultures containing these recombinants, except for 20 untested clone 12.1, produced interferon activities similar to the parental IFN- α 2, when tested on human ccl23 cells.

25 Among the 21 sequenced clones, we identified seven different crossover regions with the crossover region corresponding to the longest stretch of uninterrupted homology between the α 1 (396-452 bp) and α 2 (393-449 bp) sequence, being represented no less than 12 times. Moreover, these seven sequences code for five different α 2- α 1 hybrid interferons, only one of which was identical 30 to the α 2- α 1 hybrid interferon previously obtained by Streuli et al., supra, using conventional genetic engineering techniques.

35 Plasmid DNA extracted from the cultures of six of the selected colonies (3, 3-4, 102, 105, 107 and 110) showed heterogeneity with regard to the second BglII site

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and plasmid DNA from one of these colonies (107) also showed heterogeneity with regard to the EcoRI site. These heterogeneities may be a result of the segregation of incompletely-repaired heteroduplex strands or, alternatively, the result of transfection by several copies of recombination-competent DNA, presumably covalently linked to concatenes.

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TABLE I*

	Clone No.	No. of <u>Bgl</u> II sites	No. of <u>Pvu</u> II sites	No. of <u>Eco</u> RI sites	Region of Recombination (bp no. (2) to bp no. (1))
5	12.1	0	n.d.	n.d.	n.d.
	12.2	1	2	1	259-285
	12.3	2	2	1	454-461
	1	1	2	1	393-452
	2	2	2	0	n.d.
10	3	1+2(mix)	2	1	n.d.
	3-2	1	2	1	393-452
	3-4	1+2(mix)	2	1	n.d.
	4	1	2	1	311-318
	5	1	2	1	311-318
15	6	1	2	1	393-452
	7	2	2	0	n.d.
	8	1	2	1	393-452
	101	1	2	1	393-452 (372-394 not strictly excluded)
20	102	1+2(mix)	2	1	n.d.
	102-1	1	2	1	393-452
	102-2	2	2	1	460-482
	103	1	2	1	393-452 (372-394 not strictly excluded)
25	104	1	2	1	360-452 (probably 393-452)
	105	1+2(mix)	2	1	n.d.

30 * Abbreviations used in Table I:
"n.d." not done

TABLE I (cont.)

	Clone No.	No. of <u>Bgl</u> II sites	No. of <u>Pvu</u> II sites	No. of <u>Eco</u> RI sites	Region of Recombination by Sequencing (bp no. (2) to bp no. (1))
5	105-1	2	2	1	460-482
	106	2	2	0	n.d.
	107	1+2(mix)	2	0+1(mix)	n.d.
	107-1	1	2	1	339-350
	107-4	2	2	0	n.d.
10	108	1	2	1	393-452
	109	1	2	1	311-318
	110	1+2(mix)	2	1	n.d.
	110-1	1	2	1	393-452
	110-2	2	2	1	460-482
15	111	1	2	1	393-452
	112	1	2	1	393-452

Including additional experiments using the method of this Example I, we have isolated recombinant $\alpha 2-\alpha 1$ coding sequences having 11 different crossover regions. See Figure 6. These 11 regions are designated A through K in Figure 6. One of these crossover regions (K) had a homology of only three nucleotides, demonstrating that three nucleotides was sufficient homology between the two parental DNA sequences for recombination using the methods of this invention.

The 11 different recombinants encoded 9 different hybrid interferons. These arose from recombinants with crossovers in regions A, D, E, F, G, H and I/J. Crossovers in regions B, C, I and J produced DNA sequences differing only by silent nucleotide changes.

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We employed these recombinant α 2- α 1 DNA sequences to transform host cells and to produce the hybrid interferons encoded by them. We then analyzed the antiviral activities of crude extracts of these hybrid 5 interferons on human (WISH) cells, murine (L929) cells and bovine (MDBK) cells. The antiviral activities of these hybrid interferons, as well as those of the parental IFN- α 1 and IFN- α 2, are displayed in Figure 7.

The utility of the methods of this invention to 10 produce interferons having different properties than their parents is exemplified by the dramatic drop observed in antiviral activity on mouse cells as the COOH-terminal α 1 segment in the hybrid interferon is shortened beyond 25%.

It should of course be understood that other 15 IFN- α hybrids may be equally well produced by the methods of this invention. For example, the method chosen for preparation of the linear DNA sequence employed above to form the hybrid DNA sequences only allowed production of hybrids with the amino terminal of α 2 and the carboxy terminal of α 1, with the crossover region downstream of the BglII site of α 1. However, other restriction and digestion patterns allow us to obtain crossover in the parental 20 DNA sequences at any position or between two other pre-selected positions. Some of these alternative methods are 25 illustrated in Examples II through V, below.

Example II

In this example we provide one alternative method for preparing an α 2- α 1 hybrid DNA sequence with crossover at any position.

30 In this method, we restrict plasmid pM21 with SalI and PstI and isolate the fragment that contains the IFN- α 2 coding region. An XbaI linker is then introduced upstream of the IFN- α 1 gene in pM11kan to generate pM11kan-Xba. For this construction a 1.4 Kb SalI-EcoRI 35 1.4 Kb fragment from plasmid pGI was employed because it contained an Xba restriction site upstream of the α 1

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coding sequence. See, e.g., U. Weidle and C. Weissmann, "The 5'-Flanking Region Of A Human IFN- α Gene Mediates Viral Induction Of Transcription," Nature, 303, pp. 442-46 (1983). This construction is depicted in Figure 5. We 5 then restrict pMllkan-Xba with SalI and XbaI and isolate the SalI-XbaI fragment that contains the IFN- α 1 coding region. Other restriction sites may be equally well employed to generate the α 1 or α 2-containing fragments in this Example without departing from the scope of this 10 invention. E.g., the SalI-PstI fragment of pMllkan maybe employed to generate an α 1-containing fragment.

Ligation of these two fragments produces a DNA sequence, or more usually a concatemer thereof, comprising in sequence the α 2 coding region, an intact replicon from 15 pBR322, and the α 1 coding region. The DNA sequence also contains the resistance marker for kanamycin and the reconstructed marker for tetracycline resistance.

After transfection of calcium-treated E.coli substantially as described in Example I, that DNA sequence 20 permits the production of a variety of α 2- α 1 hybrids having the possibility of crossover at any region where the sequences of homology between the coding sequences of α 1 and α 2 are at least a series of 5 nucleotides, and more preferably at least 8-13 nucleotides.

25

EXAMPLE III

In this example, we provide another embodiment of a method for preparing an α 2- α 1 hybrid DNA sequence with the crossover in the first third of the coding regions. In this method, we restrict plasmid pM21 with 30 SalI and BglII and isolate the SalI-BglII fragment, containing the coding region for the amino terminal end of IFN- α 2. We also restrict pMllkan-Xba with XbaI and PstI and isolate the XbaI-PstI fragment, containing the coding region for IFN- α 1. Ligation of these fragments produces a 35 DNA sequence, or concatemer thereof, comprising in sequence about the first third of the α 2 coding region, an intact

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replicon from pBR322, and the α 1 coding region. Again, other restriction sites may equally well be employed to generate these fragments. E.g., the SalI-PstI fragment of pM11kan maybe employed to generate an α 1-containing fragment.

After transfection of calcium-treated E.coli, substantially as described in Example I, that DNA sequence permits the production of a variety of α 2- α 1 hybrids having the possibility of crossover in the first third of the α 2 coding region, where the required homology with the α 1 coding region exists.

EXAMPLE IV

In this example, we provide a method for preparing an α 2- α 1 hybrid DNA sequence with the crossover in the middle third of the coding regions. In this method, we 15 restrict plasmid pM21 with SalI and PvuII and isolate the SalI-PvuII fragment, containing the coding region of about the first two-thirds of IFN- α 2. We also restrict pM11Kan with SalI and BglII and isolate the SalI-BglII fragment 20 containing the about last two-thirds of the IFN- α 1 coding region. Again, other restriction fragments may also be used. E.g., an XbaI-SalI fragment of pM11Kan-Xba maybe used to generate an α 1-containing fragment.

Ligation of these fragments produces a DNA molecule, or concatemer thereof, comprising in sequence about 25 the first two-thirds of the α 2 coding region, an intact replicon from pBR322, and about the last two-thirds of the α 1 coding region.

After transfection of calcium-treated E.coli, substantially as described in Example I, that DNA sequence 30 permits the production of a variety of α 2- α 1 hybrids having the possibility of crossover in the about middle one-third of the α 2 coding region, where the required homology with the α 2 coding region exists.

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EXAMPLE V

In this example, we provide a method for preparing an $\alpha 1-\alpha 2$ hybrid DNA sequence with the crossover in the carboxy-terminal end of the $\alpha 1$ coding region. In this

5 method, we restrict plasmid pM21 with SalI and BglII and isolate the SalI-BglII fragment containing the coding region for the COOH-terminus of $\alpha 2$. We also restrict pM11Kan with SalI and PstI and isolate the shorter SalI-PstI fragment, containing the entire coding region for $\alpha 1$.

10 Ligation of these fragments produces a DNA sequence, or concatemer thereof, comprising in sequence the COOH-terminal end of the $\alpha 2$ coding region, an intact replicon from pBR322, and the entire $\alpha 1$ coding region.

After transfection of calcium-treated E.coli,

15 substantially as described above, that DNA sequence permits the production of a variety of $\alpha 1-\alpha 2$ hybrids having the possibility of crossover in the carboxy terminal end of the $\alpha 1$ coding region, where the required homology exists with the $\alpha 2$ coding region.

20 The antibiotic selection method does not apply to this example.

EXAMPLE VI

In Examples I-V the circularization step of the linear DNA sequence was done in vivo. This is the most

25 preferred method of this invention. However, circularization may also be effected in vitro and only heteroduplex repair left to take place in vivo. This example illustrates this less preferred method of this invention.

We digested pM11Kan with BglII to linearize it

30 at position 189. We also partially digested pM21 with BglII (about 60-70% of the full length linearized molecules ended at the downstream BglII site (position 446)). We then digested each of the linearized plasmid preparations with T_4 -DNA polymerase to convert the terminal

35 300-400 nucleotides of each linear DNA sequence into

single-stranded form. After mixing the two sequences in about equal proportions, we allowed the mixture to anneal and filled in any remaining gaps with DNA polymerase. We then cleaved the resulting products with SalI and circularized them in the presence of ligase using standard conditions.

We then transfected calcium-treated E.coli HB101 (rec A⁻), E.coli 803 (rec+) or E.coli SK1592 (rec A⁺ sbcB) with the resulting DNA. We obtained colonies resistant to both tetracycline and kanamycin from each strain, but among the 21 clones that we analyzed further, only 1 (an HB101 transfecant) did not have a deletion or an otherwise rearranged sequence. This clone had 2 PvuII sites, 1 EcoRI site and its region of recombination was in Region C (Figure 6). Therefore, while the in vivo process is more efficient and hence preferred, the in vitro process also permits the production of the hybrid DNAs of this invention.

EXAMPLE VII

20 In this example, we prepared recombinants of
IFN- α 2 and IFN- β . A schematic outline of this method is
depicted in Figure 8. The DNA sequence coding for IFN- β
is described, for example, in R. Deryck et al., "Isola-
tion And Structure Of A Human Fibroblast Interferon Gene",
25 Nature, 285, pp. 542-46 (1980). See also European patent
application 41313 and the clones deposited and made avail-
able in connection therewith.

30 We prepared plasmid pGB (Figure 8) by combining three DNA fragments: (1) the 0.77 Kb HincII fragment of plasmid pBR325 FIF (a gift of W. Fiers), this fragment contains the coding region for IFN- β ; (2) the 4.6 Kb partial RsaI-SalI fragment of pBR322kan (described above); and (3) the 1.2 Kb partial HincII-SalI fragment of pBR322 Bam^R (described above) in the presence of ligase. We then 35 used that plasmid to prepare transformants and selected positive clones by resistance to ampicillin, kanamycin and

tetracycline, as described above. From these positive clones, we selected one clone characterized by a plasmid having the inserts in the orientation depicted in Figure 8. We designated this plasmid pGB.

5 We next restricted pGB with SalI and HincII and isolated the 5.3 Kb SalI-HincII fragment that contains the IFN- β coding region. We also restricted pM21 with PstI and SalI and isolated the 1.7 Kb PstI-SalI fragment that contains the IFN- α 2 coding region. We then combined these 10 fragments in the presence of ligase.

15 The resulting DNA fragment (Figure 8) comprised in sequence the DNA sequence encoding IFN- β , the DNA sequences encoding kanamycin resistance and tetracycline resistance and the DNA sequence encoding IFN- α 2. Moreover, the two IFN coding sequences were in the same translational orientation relative to each other so as to permit parallel overlap of homologous sequences to form hybrids according to the methods of this invention.

20 In order to circulize the above-described DNA fragment and to form the desired hybrid DNA sequences, we transfected it into E.Coli SK 1592 and selected positive clones as before.

25 We obtained hybrids from four crossover regions: F3, F8, F10 and F15. See Figure 9. Each had the 5' part of IFN- α 2 and the 3' part of IFN- β . Recombinants in crossover regions F3, F10 and F15 were "in phase", i.e. they occur at homologous positions. Recombinants in crossover region F8 are "illegitimate" recombinants because of the repeat TGAGA homology at two positions in the IFN- β coding 30 region. See Figure 9.

35 We used these α 2- β recombinants to transform host cells and to produce the α 2- β hybrid interferons encoded by them. We then assayed the antiviral activity of the α 2- β hybrid interferons on both human and bovine cells using crude extracts and conventional methods. The results are depicted in Table II.

TABLE II

<u>Cells</u>	<u>Hybrid Interferons</u>			
	<u>F3</u>	<u>F8</u>	<u>F10</u>	<u>F15</u>
Human (WISH) Cells	-	-	-	150
5 Bovine (MDBK) Cells	-	-	50	2500

Therefore, hybrid α 2- β interferons from crossover regions F10 and F15 have antiviral activity. Moreover, the ratio of such activity on human and bovine cells is about 1:15. As a comparison, IFN- α 2 has a ratio of antiviral activity 10 on human and bovine cells of about 1:1,

Again, it should be understood that the above example is merely illustrative. Other regions of crossover between IFN- α 2 and IFN- β may be utilized and other hybrid α - β or β - α interferons may be prepared in accordance with the teachings of this invention.

EXAMPLE VIII

In this example, we prepare recombinants of human IFN- α 2 and mouse IFN- α 2. A schematic outline of this method is depicted in Figure 10.

20 As depicted in Figure 10, we prepare plasmid pM11Kan-mouse by ligation of three DNA fragments: (1) the 0.7 Kb AhaIII-PstI fragment of pMIF α 2 [G.D. Shaw et al., Nucleic Acids Res., 11, pp. 555-73 (1983)]; (2) the 0.75 kb HindIII-PstI fragment of pMIF α 2; (3) the 4.6 Kb 25 AhaIII-HindIII (partial) fragment of pM11Kan. We then restrict pM11Kan-mouse with PstI and SalI to prepare a 4.7 Kb PstI-SalI fragment containing the mouse IFN- α 2 coding region. We next combine this fragment with the 1.6 Kb AhaIII-SalI fragment from pM21 that contains the 30 amino-terminal portion of the human IFN- α 2 coding region. Upon transformation into host cells as before, we are able to generate various recombinant human α 2-mouse α 2 DNA sequences that are useful in producing human-mouse hybrid

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interferons. Again, it should be understood that other restriction sites and IFN- α genes may be used to generate such human-mouse hybrid DNA sequences and interferons in accordance with the methods of this invention.

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Claims:

1. A method for preparing a hybrid DNA sequence comprising the steps of:

5 (a) preparing a DNA fragment, or concatemer thereof, said fragment comprising in sequence one of the parental DNA sequences from which the hybrid DNA sequence is to be derived, an intact replicon such that the DNA fragment may be replicated in a host cell, and the other parental DNA sequence from which 10 the hybrid DNA sequence is to be derived, the two parental DNA sequences having a sequence of at least three nucleotides in common in the location where hybrid DNA sequence formation is sought and the direction of translation of the coding sequences in 15 the two parental sequences being the same relative to each other in the DNA fragment.

(b) selecting host cells that have been transfected with the desired hybrid DNA sequence and isolating said hybrid DNA sequence from them.

20 2. The method according to claim 1, wherein the parental DNA sequences have homologous sequences of at least 5 nucleotides.

25 3. The method according to claim 1, wherein the parental DNA sequences have homologous sequences of at least 8 nucleotides.

4. The method according to claim 1, wherein the parental DNA sequences have homologous sequences of at least 13 nucleotides.

30 5. The method of any one of claims 1 to 4, wherein the DNA fragment also comprises at least one antibiotic resistance marker.

6. The method of claim 5, wherein the DNA fragment comprises a different antibiotic resistance marker associated with each of said parental DNA sequences.

35 7. The method of claim 5, wherein the DNA fragment comprises one antibiotic resistance marker and a portion of a different antibiotic resistance marker associated

with one of said parental DNA sequences and the portion of said different antibiotic resistance marker that completes it associated with the other of said parental DNA sequences.

5 8. A method for preparing a hybrid DNA sequence comprising the steps of:

10 (a) preparing a DNA fragment, or concatemer thereof, said fragment comprising in sequence one of the parental DNA segments from which the hybrid DNA sequence is to be derived, an intact replicon such that the fragment may be replicated in a host cell, and the other of the parental DNA sequences from which the hybrid DNA sequence is to be derived, the direction of translation of the coding sequences in the two parental sequences being the same relative 15 to each other in the DNA fragment;

20 (b) forming in one of said parental DNA sequences, a sequence of at least three nucleotides, said five nucleotide sequence being identical to a DNA sequence in said other parental DNA sequence at the location in said other DNA sequence where said hybrid formation is sought;

25 (c) selecting host cells that have been transfected with the desired hybrid DNA sequence and isolating said hybrid DNA sequences from them.

9. The method of claim 8, wherein a sequence of at least 5 common nucleotides is formed in one of said parental DNA sequences.

30 10. The method according to claim 8, wherein a sequence of at least 13 common nucleotides is formed in one of said parental DNA sequences.

11. The method of any one of claims 8 to 10, wherein said step of forming said common nucleotide sequence in one of said parental DNA sequences takes place before the step of preparing said linear DNA fragment.

35 12. The method of any one of claims 8 to 11, wherein the DNA fragment also comprises at least one antibiotic resistance marker.

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13. The method of claim 12, wherein the DNA fragment comprises a different antibiotic resistance marker associated with each of said parental DNA sequences.

5 14. The method of claim 12, wherein the DNA fragment comprises one antibiotic resistance marker and a portion of a different antibiotic resistance marker associated with one of said parental DNA sequences and the portion of said different antibiotic resistance marker that complete it associated with the other of said 10 parental DNA sequences.

15. The method of claim 1 or 8, wherein said DNA fragment is rendered partially single stranded at its ends and annealed before the step of transfecting said host with the fragment.

15 16. The method of any one of the preceding claims, wherein said parental DNA sequences are selected from the group consisting of DNA sequences encoding human α interferons, animal α interferons, human β interferons, animal β interferons, human γ interferons and animal γ 20 interferons.

17. The method of any one of claims 1-16, wherein said parental DNA sequences are selected from the group consisting of DNA sequences encoding human and animal lymphokines.

25 18. The method of any one of claims 1-16, wherein said parental DNA sequences are selected from the group consisting of DNA sequences encoding one or more of the antigens of foot and mouth disease virus.

19. The method according to claim 6, 7, 13 or 30 20, wherein said step of selecting said host cells comprises the steps of growing the transformed host cells on agar plates containing both antibiotics.

20. A hybrid DNA sequence prepared by the method of any one of the preceding claims.

35 21. A hybrid DNA sequence comprising at least two connected sequences of nucleotides, each connected DNA sequence being derived from a different parental DNA

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sequence, the first sequence of nucleotides being connected to the second sequence of nucleotides in the same reading frame so as to maintain constant that reading frame in each sequence through a DNA sequence of at least three 5 nucleotides that was common to both parental DNA sequences at the location where hybrid formation was sought.

22. The hybrid DNA sequence according to claim 21, wherein these are at least five nucleotides that were common to both parental DNA sequences.

10 23. The hybrid DNA sequence according to claim 21 or 22, wherein said parental DNA sequences are selected from the group consisting of DNA sequences encoding human α interferons, animal α interferons, human γ interferons, animal β interferons, human γ interferons and 15 animal γ interferons.

24. The hybrid DNA sequence according to claim 21 or 22, wherein said parental DNA sequences are selected from the group consisting of DNA sequences encoding human and animal lymphokines.

20 25. The hybrid DNA sequence according to claim 21 or 22, wherein said parental DNA sequences are selected from the group consisting of DNA sequences encoding one or more of the antigens of foot and mouth disease virus.

25 26. A hybrid polypeptide produced by a method comprising the steps of culturing a host transformed with a hybrid DNA sequence selected from the group consisting of hybrid DNA sequences prepared by the methods of any one of claims 1 to 20 and the hybrid DNA sequences of any one 30 of claims 21 to 25 and collecting said polypeptide.

27. A hybrid polypeptide comprising at least two connected sequences of amino acids, each connected amino acid sequence being derived from a different parental polypeptide, the first sequence of amino acids being 35 connected to the second sequence of amino acids through an amino acid sequence of at least one amino acid that was

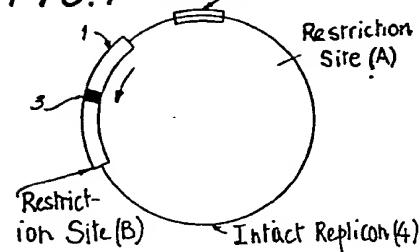
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common to both parental polypeptides at the location where hybrid formation was sought.

28. The hybrid polypeptide according to
claim 27, wherein at least two amino acids were common to
5 both parental polypeptides at the location where hybrid
formation was sought.

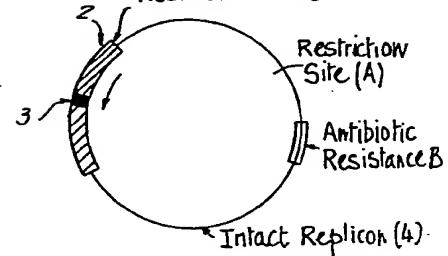
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FIG. 1 -Antibiotic Resistance A



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Restriction Site B

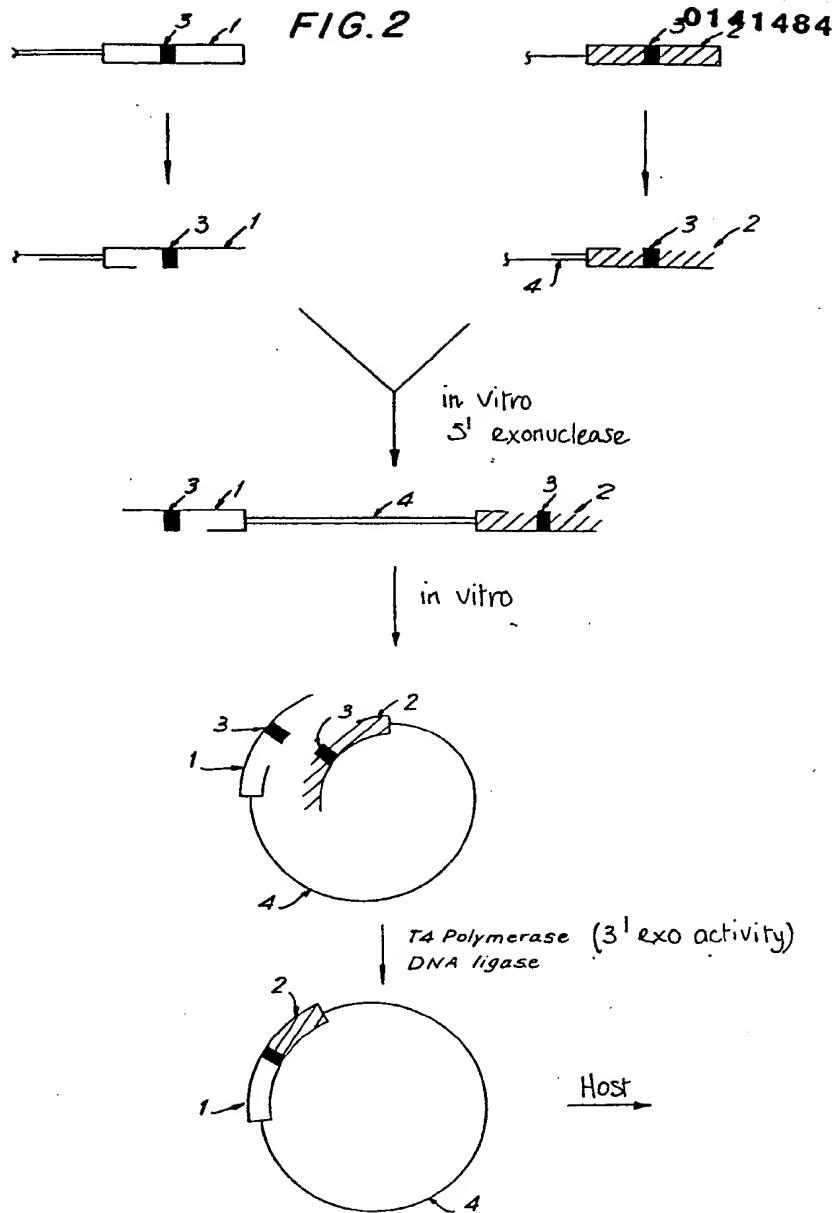


The diagram shows a horizontal pipe with a cross-hatched section representing a restriction. An arrow labeled '3' points to the center of this section. An arrow labeled '2' points to the pipe wall on the right side of the restriction. A vertical arrow labeled '1' points downwards from the top of the pipe. A second pipe section labeled '(B)' is shown to the left of the restriction. A third pipe section labeled 'Restriction Site (B)' is shown to the right of the restriction.

↓
Restriction (B)

Restriction (B)

FIG. 2



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FIG. 3

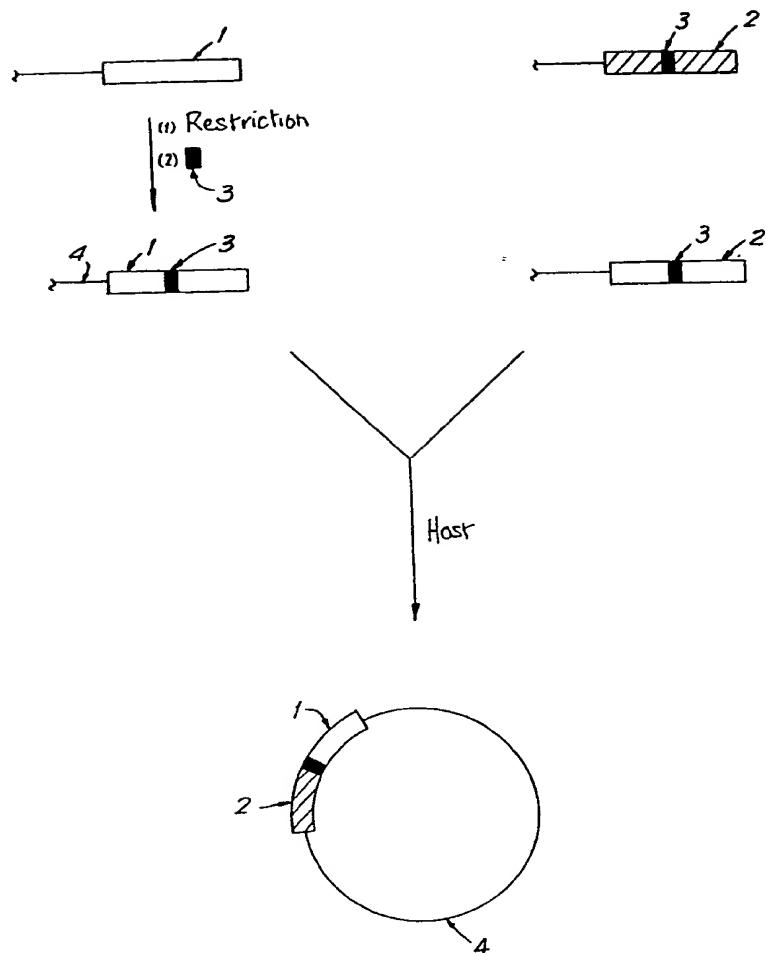


FIG. 4

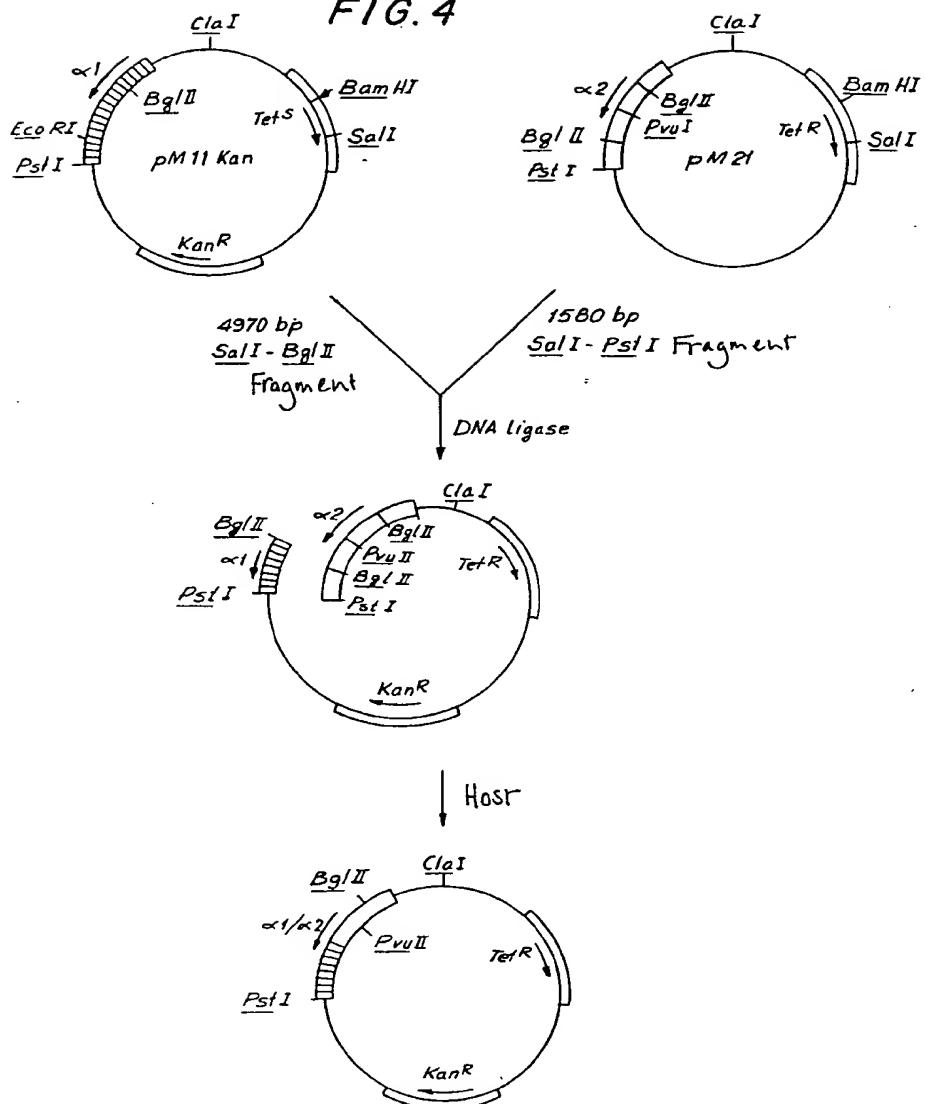


FIG. 5

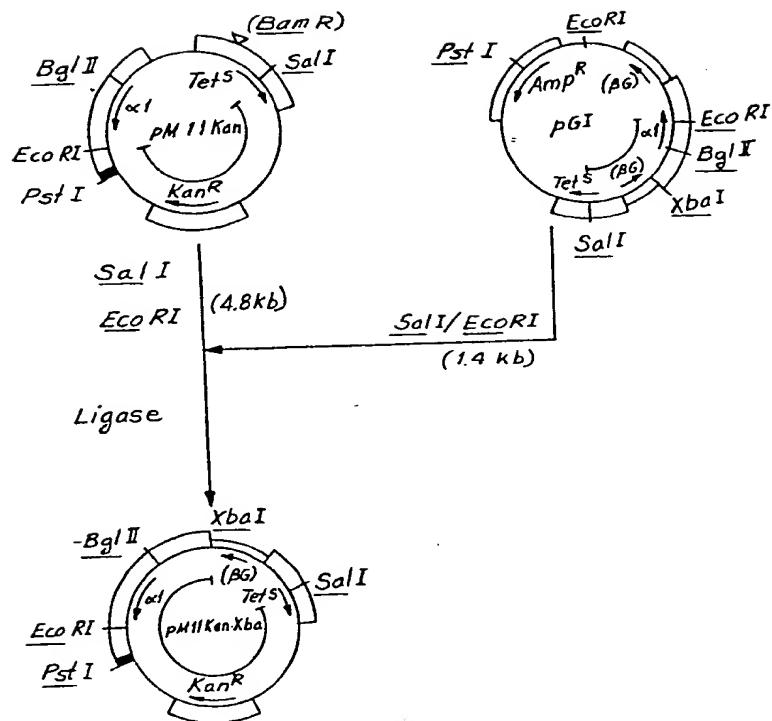


FIGURE 6A

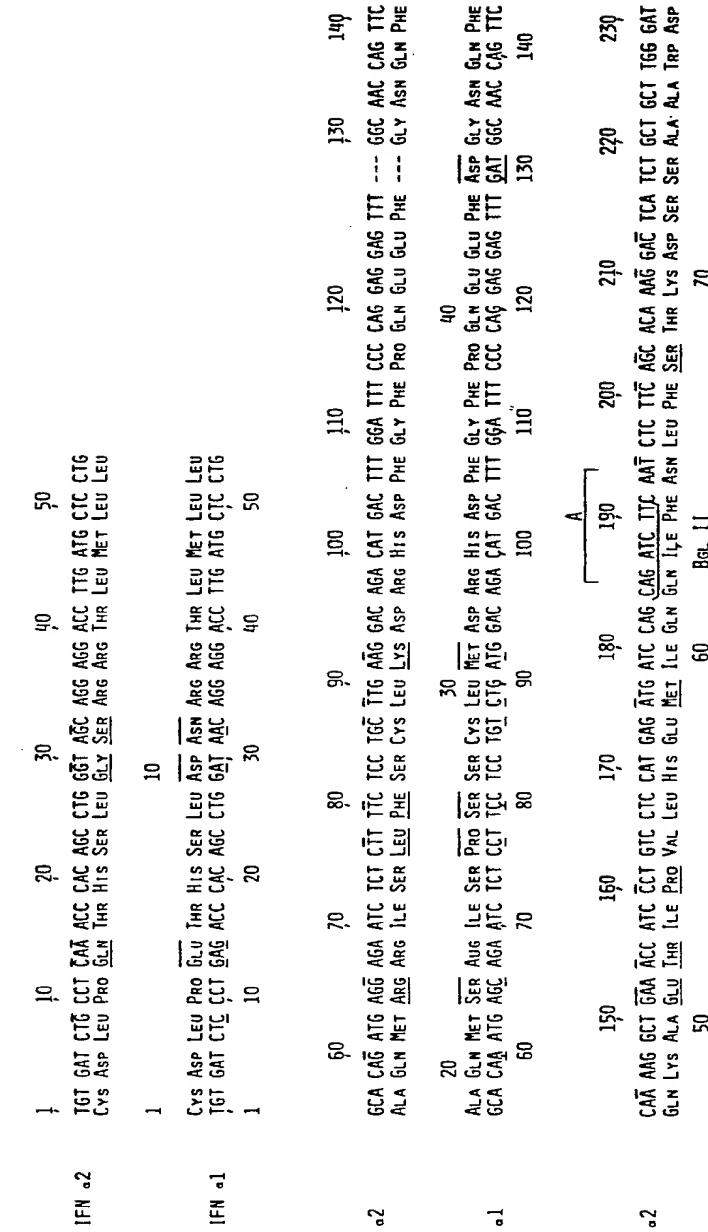


FIGURE 6B

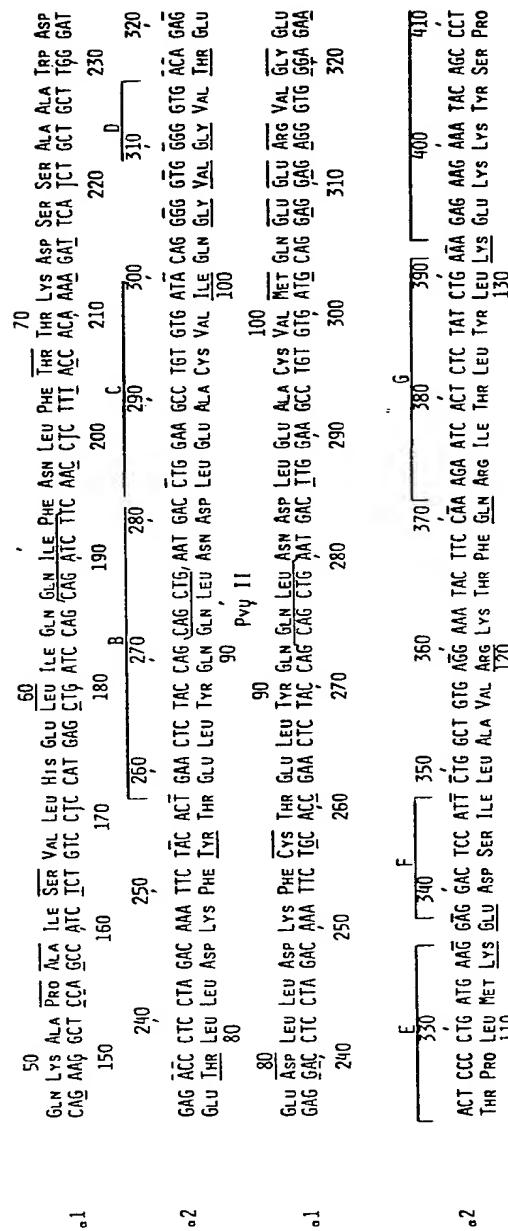
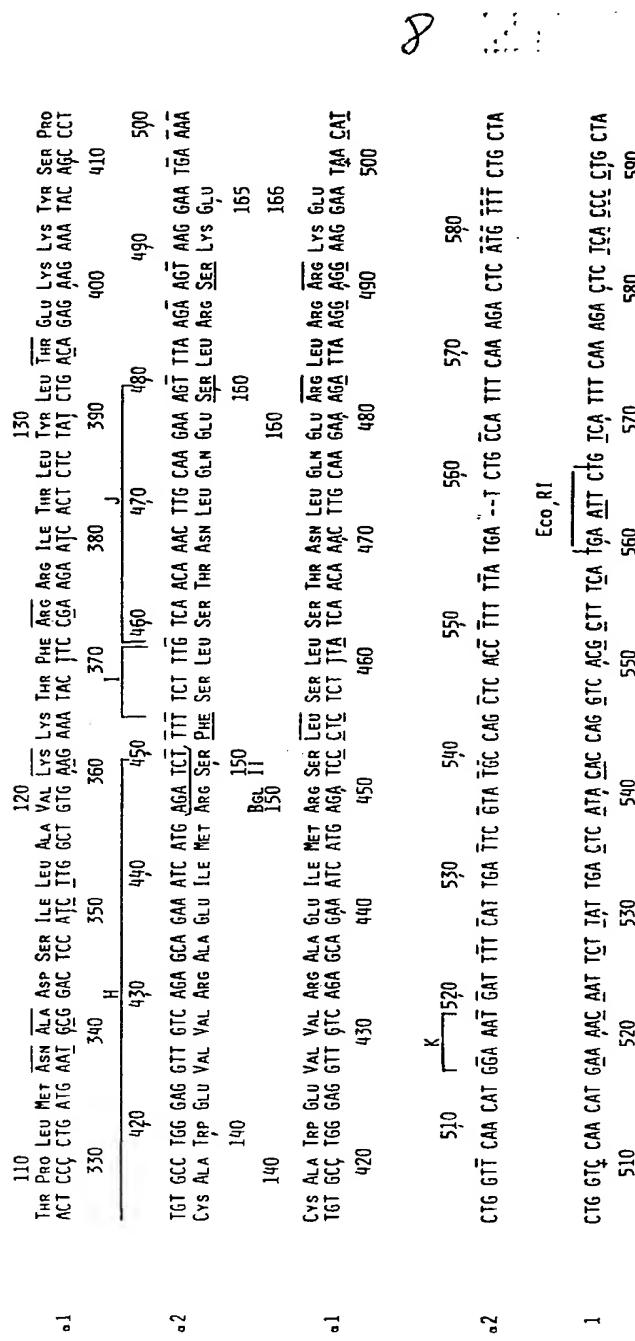


FIGURE 6C



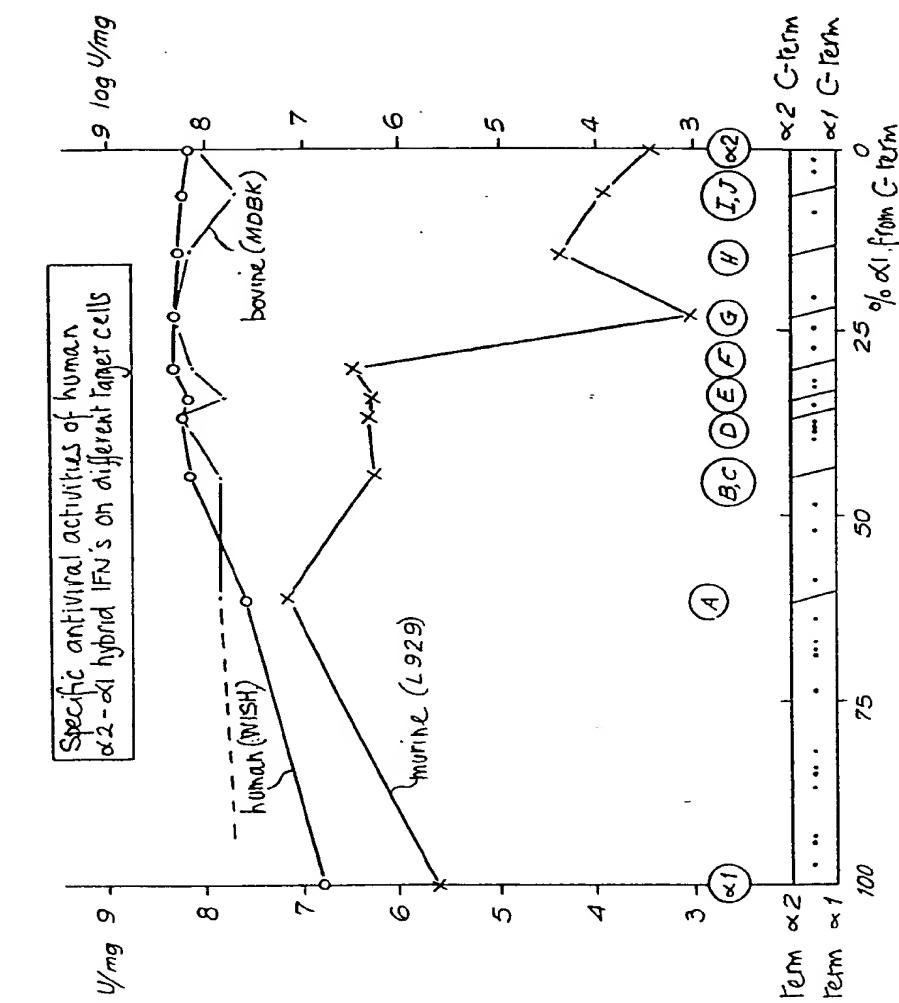
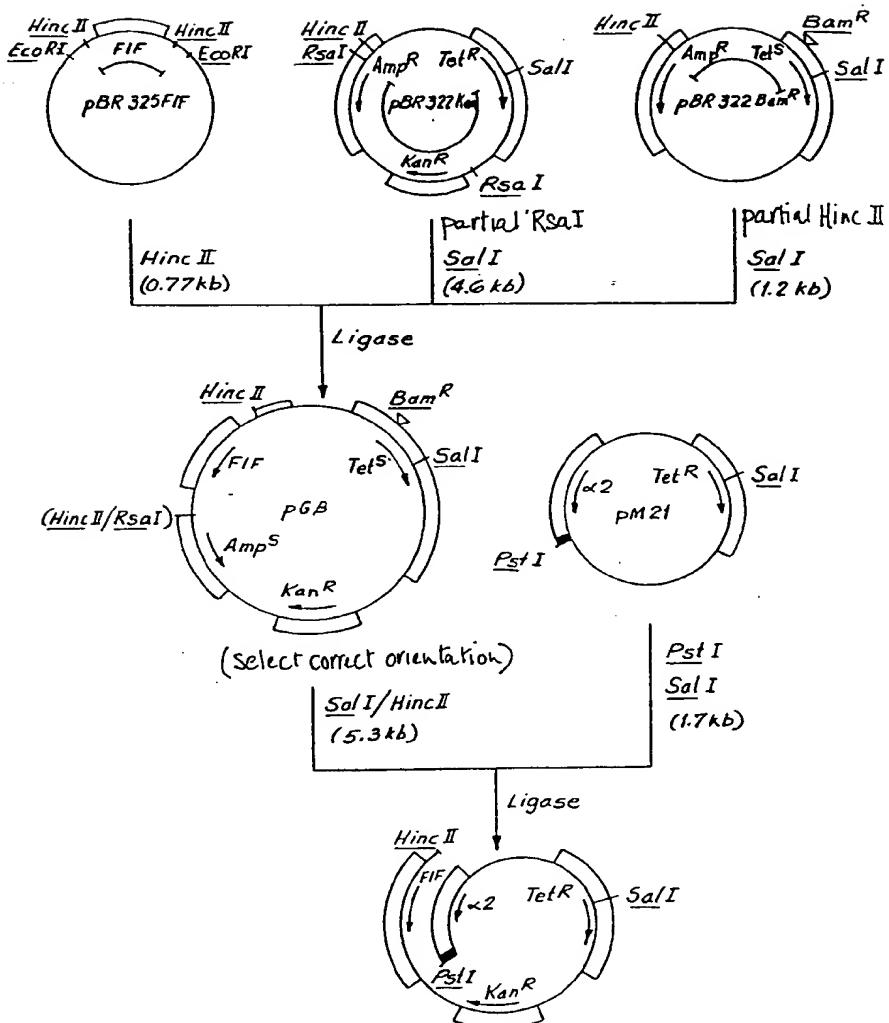


FIG. 8



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FIG. 9

B AT GAG CTA CAA CTT GCT TGG A... ... TT CCT ACA AAG AAG CAG CAA TTT TC
 a2 TG TGA TCT GCC TCA AAC CCA CAG CCT GGG TAG CAG GAG GAC CTT ..

B AGT GTC AGA AGC TCC TGT GGC AAT TGA ATG GGA G... ... GC TTG AAT AT
 a2 GA TGC TCC TGG CAC AGA TGA ... GGA GAA TCT CTC TTT TCT CC

B TGC CTC AAG GAC AGG ATG AAC TTT GAC ATC CCT GAG GAG ..A TTA AGC AG
 a2 TGC TTG AAG GAC AGA CAT GAC TTT GGA TTT CCC CAG GAG GAG TTT GGC A.

B CTG CAG CAG TTC CAG AAG GAG GAC GCC GCA TTG ACC ATC TAT GAG ATG CT
 a2 ... AC CAG TTC CAA AAG GCT GAA ACC ATC CCT GTC CTC CAT GAG ATG AT

B CCA GAA CAT CTT TGC TAT TTT CAG ... ACA AGA TTC ATC TAG CAC TGG CT
 a2 CCA GCA GAT CTT CAA TCT CTT CAG CAC AAA GGA CTC ATC T... .GC TGC TT

B GGA ^{f3} ATG AGA CTA ^{f8} TTG ATG ACC TCC TGG CTA ATG TCT ATC ATC AGA TA
 a2 GGG ~~ATG AGA CTC~~ TCC TAG ACA AAT TCT ACA CTG AAC TCT ACC AGC AGC TG

B AAC CAT CTG AAG ACA GTC CTG GAA GAA AAA CT GGA GAA AGA AG
 a2 AAT GAC CTG GAA G... ... C CTG TGT GAT ACA GGG GGT GGG GGT GAC AGA GA

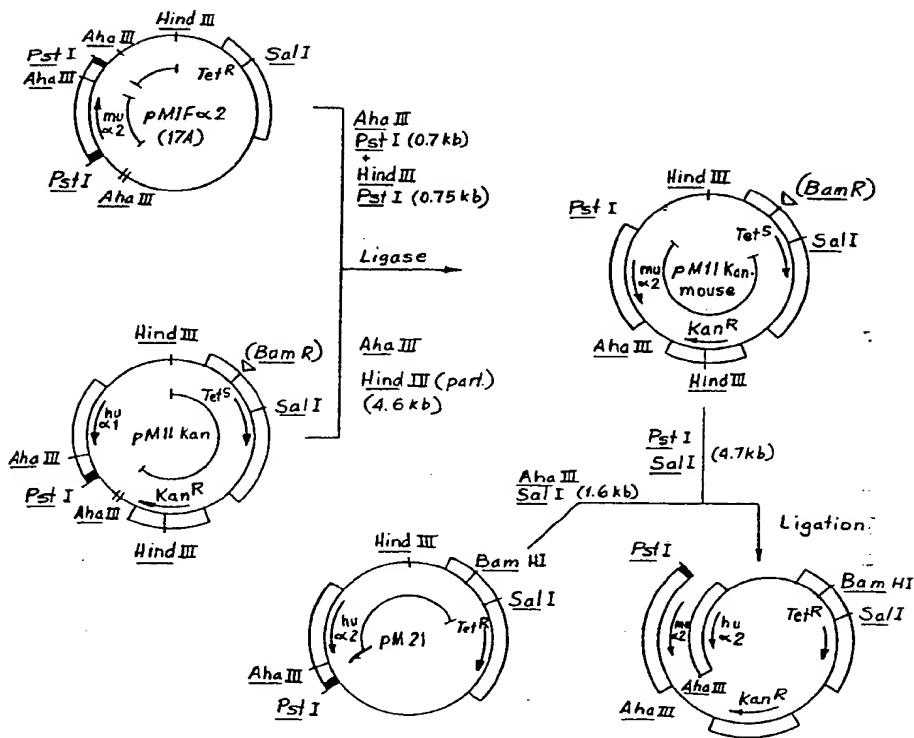
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 a2 CTC CCC TGA TGA AGG AGG ACT C... ... CAT TCT GGC TGT GAG GAA ATA CT

B ATG GGA GGA TTC TGC ATT ACC TGA AGG CCA AGG AGT ACA GTC ACT ^{f10} GTG CC
 a2 TCC AAA GAA TCA CTC TCT ATC TGA AAG AGA AGA AAT ACA GCC CTT ~~GTG~~ CC

B TGG ACC ATA ^{f15} GTC AGA GTG GAA ATC CTA AGG AAC TTT TAC TTC ATT AAC AG
 a2 TGG GAG GTT ~~GTC AGA GCA~~ GAA ATC ATG A,G ATC TTT TTC TTT GTC AAC AA

B ACT TAC AGG TTA CCT CCG AAA C
 a2 ACT TGC AAG AAA GTT TAA GAA GT. AAG GAA

FIG. 10



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